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Original Research Paper

Dentistry

GENDER DETERMINATION FROM MEASUREMENTS OF MAXILLARY AND MANDIBULAR DENTAL ARCHES – AN OCCLUSAL RADIOGRAPHIC STUDY

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ABSTRACT Sex estimation is one of the essential parameters for the human Identification in forensic analysis. Resilience of palatal structures and mandible to traumatic and natural forces is useful in several forensic situations. Radiography plays a vital role in forensic dentistry to uncover hidden facts which cannot be seen by means of physical examination. The occlusal radiograph gives a bird's eye view of entire maxillary and mandibular arches, and useful in evaluation of dental arches. **Aims:** To assess the usefulness of linear measurements of maxillary and mandibular dental arches on occlusal radiographs for gender determination. **Settings And Design:** The study constituted of 60 subjects (30 males and 30 females) with age range of 21-30 years. 120 cross sectional maxillary and mandibular occlusal radiographs were taken and traced. Maxillary and mandibular dental arch linear measurements on occlusal radiographs were made related to Inter canine, Inter 1st premolar, Inter 2nd premolar, Inter 1st molar, and Inter 2nd molar widths. **Statistical Analysis Used:** Independent Student t Test and Discriminant function analysis. **Results:** The Inter 2nd molar width in both dental arches was the best predictor for gender determination. The Predicted gender model showed a sensitivity of 60% & 70% and specificity of 70% & 60% in the maxillary and mandibular arches respectively with overall accuracy of 65% in both the arches. **Conclusion:** The present study shows a significant sexual dimorphism in linear measurements of maxillary and mandibular dental arches and can be very useful for gender determination in forensic science.

KEYWORDS : Gender determination; sexual dimorphism; Linear measurements; Dental arches; Occlusal radiographs

INTRODUCTION

Forensic dentistry has been defined by the Federation Dentaire Internationale (FDI) as that branch of dentistry which, in the interest of justice, deals with the proper handling and examination of dental evidence, and with the proper evaluation and presentation of dental findings.[1] Human Identification connotes determination or establishment of individuality of a person living or dead.[2,3] The call for forensic identification arises for humanitarian reasons, in mass disasters, to resolve criminal investigations and legal problems of insurance settlements, inheritance, funeral rites and for grief resolution of family and friends. The big four of forensic identification are determination of age, sex, stature, and ethnicity.[2] Anthropology is employed in a forensic setting to help create a biological profile of unknown skeletal or decomposed remains in order to arrive at conclusions or inferences regarding provenance. Sex determination is one of the key questions addressed when formulating this profile and its knowledge immediately eliminates 50% of the population from the process of identification. Krogman and Iscan ranked Skeletal regions in order of their accuracy for determining sex are the pelvis 95%, the skull 92%, the mandible 90% and long bones 80%. The craniofacial structures have the added advantage of being composed largely of hard tissue, which is relatively indestructible,[4] the skull is usually better preserved.[5] Resilience of palatal structures to traumatic and natural forces is useful in several forensic situations. The mandible is composed of a dense layer of compact bone making it very durable and hence remains well preserved than many other bones. Radiography being a non-destructive method also plays a vital role in forensic dentistry to uncover hidden facts which cannot be seen by means of physical examination. Comparison between ante-mortem and post-mortem dental records and radiographs produce results with a high degree of reliability and relative simplicity.[6] The occlusal radiograph gives a bird's eye view of entire maxillary and mandibular arches, and it is useful in evaluation of dental arches which are influenced by the basal bones and teeth. With this background, the present study was undertaken to assess the usefulness of linear measurements of maxillary and mandibular dental arches on occlusal radiographs for gender determination.

MATERIALS AND METHODS:

Subjects were selected from patients reporting to Department of Oral medicine and Radiology, M.R. Ambedkar Dental college and Hospital, Bangalore, Karnataka, India by random sampling method after informed consent. The study was performed on a total of 60 healthy subjects comprising of 30 males and 30 females with an age range of 21-30 years. A detailed case history was recorded to ensure the selection of ideal subjects.

Exclusion Criteria:

1. Developmental disturbances of teeth and jaws.
2. Missing teeth (except for third molars).
3. Teeth with dental caries, periodontal and periapical diseases.
4. Teeth with wasting diseases.
5. Teeth with extensive restorations and crowns.
6. Pregnancy and lactation

METHOD:

The present study was approved by the ethical committee and review board of M. R. Ambedkar Dental College and Hospital, Bangalore. 120 cross sectional maxillary and mandibular occlusal radiographs were taken for 60 subjects. All occlusal radiographs were obtained using Carestream CS2100 model 70 Kvp intraoral x-ray machine and using occlusal type films Carestream – Insight (Kodak) Films IO-41, size 4: 57mm×76mm. Radiographs were taken following radiation protection protocol as per National Council on Radiation Protection guidelines. The exposed occlusal films were processed using manual processing method. The maxillary and mandibular dental arches were traced on the occlusal radiographs. Capital letters were attributed to the maxillary arch and small letters to the mandibular arch.

Linear measurements were made in millimeters related to the maxillary and mandibular dental arches width (I) canine portion - linear measure 'CC' (maxillary arch) and 'cc' (mandibular arch), corresponding to a line drawn from the most vestibular portions of right and left canine.

(II) 1st premolar portion - linear measure '1PP' (maxillary arch) and '1pp' (mandibular arch), corresponding to a line drawn from the most vestibular portions of right and left 1st premolar.

(III) 2nd premolar portion – linear measure '2PP' (maxillary arch) and '2pp' (mandibular arch), corresponding to a line drawn from the most vestibular portions of right and left 2nd premolar.

(IV) 1st molar portion – linear measure '1MM' (maxillary arch) and '1mm' (mandibular arch), corresponding to a line drawn from the most vestibular portions of right and left 1st molar.

(V) 2nd molar portion – linear measure '2MM' (maxillary arch) and '2mm' (mandibular arch), corresponding to a line drawn from the most vestibular portions of right and left 2nd molar.

Statistical Analysis:
Independent Student t Test and Discriminant function analysis.

RESULTS:
- The mean age of males was 23.53 years and that of females was 23.33 years.
- Equal gender distribution was observed in the total sample
- The mean value of maxillary intercanine width (CC) and mandibular inter 1st premolar width (1pp) were higher in males when compared to females and their differences were found to be statistically insignificant ($p > 0.05$).
- The mean value of maxillary inter 1st premolar width (1PP), inter 2nd premolar width (2PP), inter 1st molar width (1MM), inter 2nd molar width (2MM) and mandibular inter 2nd premolar width (2pp), inter 1st molar width (1mm), inter 2nd molar width (2mm) were higher in males when compared to females and their differences were found to be statistically significant ($p < 0.05$).
- The mean value of mandibular intercanine width (cc) was slightly lower in males when compared to females and the difference was found to be statistically insignificant ($p > 0.05$).
- On subjecting the data to discriminant function analysis, the Gender Prediction equation from the study sample was quoted as follows:

For Maxillary Arch: 18.57 - 1.00 x 2MM
For Mandibular Arch: 20.69 - 1.00 x 2mm

- The centroid discriminant score using maxillary arch parameters for males was 0.445 and for females - 0.445 and using mandibular arch parameters for males was 0.443 and for females - 0.443
- Using Discriminant Functional Analysis, 65.0 % correct classification is achieved with 2MM in Maxillary Arch and 2mm in Mandibular Arch. This indicates that linear measurement of 2MM and 2mm are fair indicators for sex determination with an accuracy of 65%

TABLE 1. MEAN AGE DISTRIBUTION IN TOTAL SAMPLE

TOTAL SAMPLE	AGE RANGE (YEARS)	MEAN AGE (YEARS)
MALES	21-30	23.53
FEMALES	21-30	23.33

GRAPH 1: MEAN AGE DISTRIBUTION IN TOTAL SAMPLE

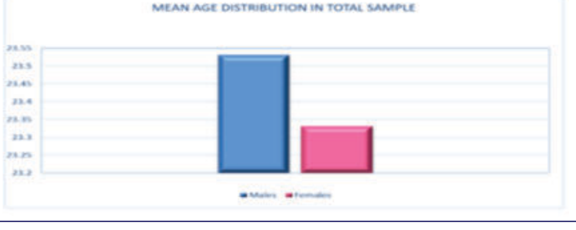

TABLE 2. GENDER DISTRIBUTION IN TOTAL SAMPLE

GENDER	N	%
MALES	30	50
FEMALES	30	50
TOTAL	60	100

Out of 60 (100%), male subjects were 30 (50%) and female subjects were 30 (50%)

GRAPH 2: GENDER DISTRIBUTION IN TOTAL SAMPLE

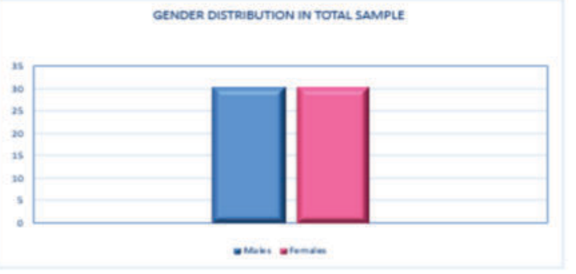

TABLE 3: COMPARISON OF MAXILLARY INTER CANINE WIDTH (CC) VALUES BETWEEN MALES AND FEMALES:

Parameters	Gender	N	Mean	SD	Mean Diff	95% Conf. Interval Lower	95% Conf. Interval Upper	P-Value
CC	Males	30	35.93	2.74	0.82	-0.61	2.25	0.26
	Females	30	35.11	2.79				

GRAPH 3: COMPARISON OF MAXILLARY INTER CANINE WIDTH (CC) VALUES BETWEEN MALES AND FEMALES

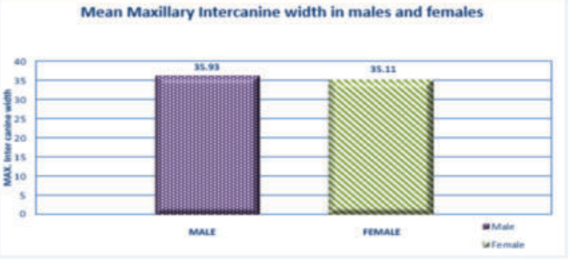

TABLE 4: COMPARISON OF MAXILLARY INTER 1ST PREMOLAR WIDTH (1PP) VALUES BETWEEN MALES AND FEMALES:

Parameters	Gender	N	Mean	SD	Mean Diff	95% Conf. Interval Lower	95% Conf. Interval Upper	P-Value
1PP	Males	30	45.40	2.65	2.00	0.51	3.48	0.009*
	Females	30	43.40	3.07				

*denotes statistically significant difference

GRAPH 4: COMPARISON OF MAXILLARY INTER 1ST PREMOLAR WIDTH (1PP) VALUES BETWEEN MALES AND FEMALES

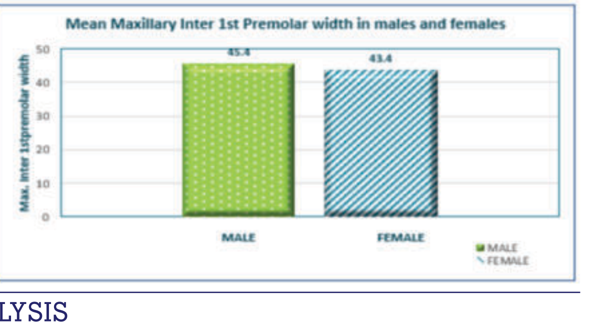

TABLE 5: COMPARISON OF MAXILLARY INTER 2nd PREMOLAR WIDTH (2PP) VALUES BETWEEN MALES AND FEMALES:

Parameters	Gender	N	Mean	SD	Mean Diff	95% Conf. Interval		P-Value
						Lower	Upper	
2PP	Males	30	50.82	2.71	1.68	0.30	3.06	0.02*
	Females	30	49.14	2.62				

*denotes statistically significant difference

GRAPH 5: COMPARISON OF MAXILLARY INTER 2nd PREMOLAR WIDTH (2PP) VALUES BETWEEN MALES AND FEMALES

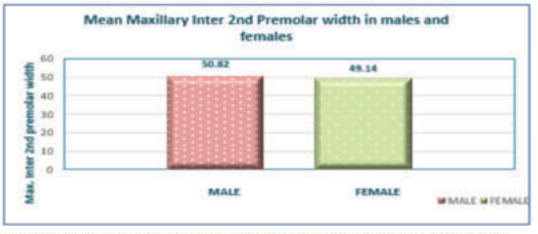

TABLE 6: COMPARISON OF MAXILLARY INTER 1ST MOLAR WIDTH (1MM) VALUES BETWEEN MALES AND FEMALES:

Parameters	Gender	N	Mean	SD	Mean Diff	95% Conf. Interval		P-Value
						Lower	Upper	
1MM	Males	30	57.55	3.22	2.10	0.50	3.70	0.01*
	Females	30	55.44	2.98				

*denotes statistically significant difference

GRAPH 6: COMPARISON OF MAXILLARY INTER 1ST MOLAR WIDTH (1MM) VALUES BETWEEN MALES AND FEMALES

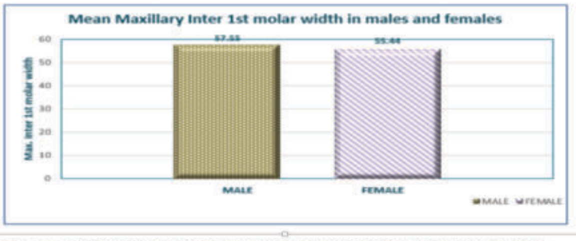

TABLE 7: COMPARISON OF MAXILLARY INTER 2ND MOLAR WIDTH (2MM)

TABLE 7: COMPARISON OF MAXILLARY INTER 2ND MOLAR WIDTH (2MM)

VALUES BETWEEN MALES AND FEMALES:

Parameters	Gender	N	Mean	SD	Mean Diff	95% Conf. Interval		P-Value
						Lower	Upper	
2MM	Males	30	63.65	3.49	2.98	1.25	4.71	0.001*
	Females	30	60.67	3.19				

*denotes statistically significant difference

GRAPH 7: COMPARISON OF MAXILLARY INTER 2ND MOLAR WIDTH (2MM) VALUES BETWEEN MALES AND FEMALES

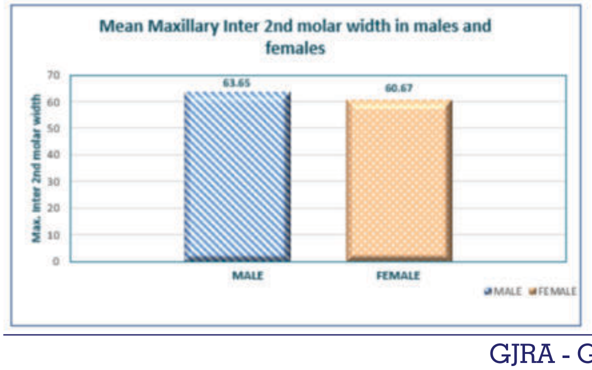

TABLE 8: COMPARISON OF MANDIBULAR INTER CANINE WIDTH (cc) VALUES BETWEEN MALES AND FEMALES:

Parameters	Gender	N	Mean	SD	Mean Diff	95% Conf. Interval		P-Value
						Lower	Upper	
cc	Males	30	28.42	2.25	-0.20	-1.24	0.85	0.71
	Females	30	28.62	1.76				

GRAPH 8: COMPARISON OF MANDIBULAR INTER CANINE WIDTH (cc) VALUES BETWEEN MALES AND FEMALES

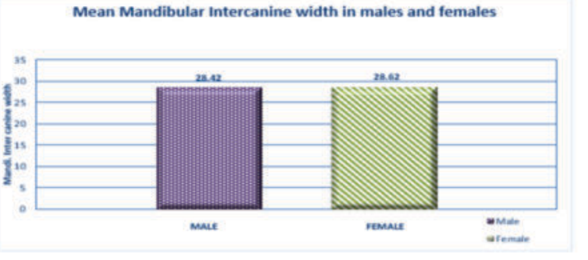

TABLE 9: COMPARISON OF MANDIBULAR INTER 1st PREMOLAR WIDTH (1pp) VALUES BETWEEN MALES AND FEMALES:

Parameters	Gender	N	Mean	SD	Mean Diff	95% Conf. Interval		P-Value
						Lower	Upper	
1pp	Males	30	38.91	2.91	0.19	-1.18	1.55	0.78
	Females	30	38.72	2.34				

GRAPH 9: COMPARISON OF MANDIBULAR INTER 1st PREMOLAR WIDTH (1pp) VALUES BETWEEN MALES AND FEMALES

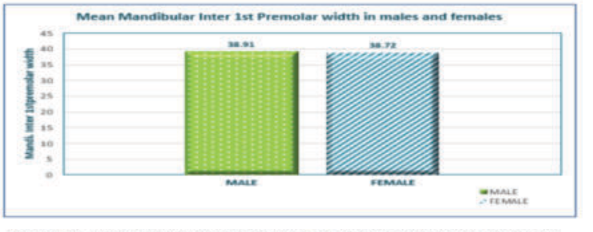

TABLE 10: COMPARISON OF MANDIBULAR INTER 2nd PREMOLAR WIDTH (2pp) VALUES BETWEEN MALES AND FEMALES:

Parameters	Gender	N	Mean	SD	Mean Diff	95% Conf. Interval		P-Value
						Lower	Upper	
2pp	Males	30	46.29	1.76	1.46	0.34	2.57	0.01*
	Females	30	44.83	2.50				

*denotes statistically significant difference

TABLE 10: COMPARISON OF MANDIBULAR INTER 2nd PREMOLAR WIDTH (2pp) VALUES BETWEEN MALES AND FEMALES

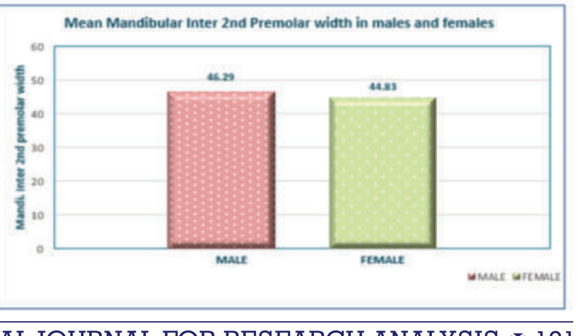

TABLE 11: COMPARISON OF MANDIBULAR INTER 1ST MOLAR WIDTH (1mm) VALUES BETWEEN MALES AND FEMALES:

Parameters	Gender	N	Mean	SD	Mean Diff	95% Conf. Interval		P-Value
						Lower	Upper	
1mm	Males	30	54.56	2.45	1.89	0.42	3.36	0.01*
	Females	30	52.66	3.18				

*denotes statistically significant difference

GRAPH 11: COMPARISON OF MANDIBULAR INTER 1ST MOLAR WIDTH (1mm) VALUES BETWEEN MALES AND FEMALES

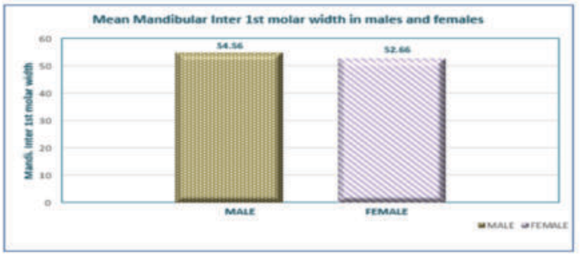

TABLE 12: COMPARISON OF MANDIBULAR INTER 2ND MOLAR WIDTH (2mm) VALUES BETWEEN MALES AND FEMALES:

Parameters	Gender	N	Mean	SD	Mean Diff	95% Conf. Interval		P-Value
						Lower	Upper	
2mm	Males	30	62.19	2.74	2.55	1.03	4.07	0.001*
	Females	30	59.64	3.14				

*denotes statistically significant difference

GRAPH 12: COMPARISON OF MANDIBULAR INTER 2ND MOLAR WIDTH (2mm) VALUES BETWEEN MALES AND FEMALES

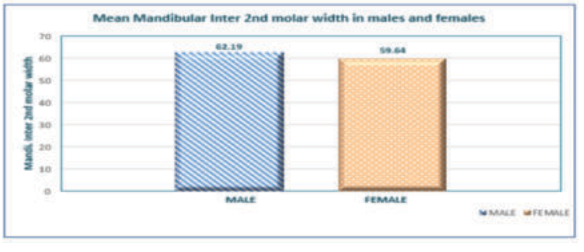

TABLE 13: DETERMINATION OF WILK'S LAMBDA AMONG THE SIGNIFICANT PARAMETERS IN MAXILLARY ARCH FOR DISCRIMINATION BETWEEN GENDERS:

PARAMETERS	WILKS' LAMBDA	F	DF1	DF2	P-VALUE
1PP	0.889	7.251	1	58	0.009*
2PP	0.907	5.966	1	58	0.02*
1MM	0.894	6.899	1	58	0.01*
2MM	0.830	11.875	1	58	0.001*

*denotes statistically significant

At each step, the variable that minimizes the overall Wilks' Lambda will enter into discriminant model.

TABLE 14: DISCRIMINANT FUNCTION COEFFICIENTS FOR GENDER DETERMINATION AMONG THE MAXILLARY ARCH PARAMETERS THAT ENTERED THE ANALYSIS

Variables	Unstd. Coefficient	Str. Matrix	Std. Coefficient	Group Centroids		Sectioning Point
				Males	Females	
2MM	0.30	1.00	1.00	0.445	-0.445	1.00
Constant	-18.57					

TABLE 15: GROUP MEMBERSHIP MODEL FOR GENDER PREDICTION IN MAXILLARY ARCH BY 2MM:

GROUPING TYPE	EXPRESSION	GENDER	PREDICTED GROUP MEMBERSHIP		
			MALES	FEMALES	TOTAL
Original	n	Males	18	12	30
		Females	9	21	30
	%	Males	60.0	40.0	100
		Females	30.0	70.0	100

TABLE 16: DETERMINATION OF WILK'S LAMBDA AMONG THE SIGNIFICANT PARAMETERS IN MANDIBULAR ARCH FOR DISCRIMINATION BETWEEN GENDERS:

PARAMETERS	WILKS' LAMBDA	F	DF1	DF2	P-VALUE
2pp	0.895	6.826	1	58	0.01*
1mm	0.897	6.665	1	58	0.01*
2mm	0.838	11.241	1	58	0.001*

At each step, the variable that minimizes the overall Wilks' Lambda will enter into discriminant model.

TABLE 17: DISCRIMINANT FUNCTION COEFFICIENTS FOR GENDER DETERMINATION AMONG THE MANDIBULAR ARCH PARAMETERS THAT ENTERED THE ANALYSIS:

Variables	Unstd. Coefficient	Str. Matrix	Std. Coefficient	Group Centroids		Sectioning Point
				Males	Females	
2mm	0.34	1.00	1.00	0.443	-0.443	1.00
Constant	-20.69					

DISCUSSION:

The mean age of males was 23.53 years and that of females was 23.33 years. This is in accordance with studies conducted by Santos et al,[11] R.S. Sathawane et al,[7] K.N. Maloth et al,[8] where similar age distribution was observed. In terms of absolute growth, midfacial heights are expected to increase 10 to 12 mm in females and 12 to 14 mm in males between 4 and 17 years of age. Palatal length is expected to increase 8 to 10 mm over the same time period. Sexual dimorphism increases substantially throughout the midfacial complex during adolescence, with differences of approximately 4 mm in maxillary length (anterior nasal spine to posterior nasal spine) and upper facial height (nasion to anterior nasal spine) at 17 years of age. Males also have significantly wider midfaces than females, with differences approximating 5 to 7 mm during late adolescence. The primary reason that adult males have larger craniofacial features than adult females is the 2 extra years of childhood growth that males have; males enter the adolescence phase of growth at approximately 12 years of age, while females enter at 10 years. Males are also larger than females because they experience a more intense adolescent spurt.

Sex differences in mandibular growth are evident at the earliest ages and become pronounced during adolescence. At birth, males have significantly larger mandibles than do females. Sex differences, which are greatest for overall length, followed by corpus length and ramus height, respectively, range from 0 to 2 mm between 1 and 12 years of age, when males initiate their adolescent phase of growth. Mandibular dimorphism increases to 4 to 8 mm by the end of adolescent growth phase.

Maxillary arch perimeter from first molar to first molar increases 4 to 5 mm during early mixed dentition and then decreases approximately 4 mm during late mixed dentition, resulting in only a slight overall increase between 5 and 18 years of age. Mandibular arch perimeter, from first molar to first molar, on the other hand, increases approximately 2 mm during early mixed dentition and decreases 4 to 6 mm during late mixed dentition, resulting in overall decreases of 3.5 and 4.5 mm in males and females, respectively.[9] The wasting diseases of the teeth in the age group from 21 to 30 years are minimal.

Within this context the selection of the above said age group in this study is attributed to the fact that the growth and development of the dental arches attain stability at the end of late adolescence period.

The difference in maxillary intercanine width was found to be statistically insignificant (p - value 0.26 > 0.05) and is in agreement with the study conducted by Rani S T et al.[10] And in disagreement with studies conducted by Santos L et al,[11] R.S. Sathawane et al,[7] Thumula Reshmi et al,[12] Maloth KN et al,[8] Matthew Forster et al,[13] Jonathan Daniel et al,[14] G Venkat Rao et al,[15] Manisha Jakhar et al,[16] Shubha C et al,[17] Dilpreet Singh et al,[18] Amina Bano et al.[19] Because of the lowered positioning of tongue, the balance between the tongue and buccinators muscle (buccinators mechanism) might be disturbed and this can be a reason for the arch constriction in maxilla. Functional matrix theory also suggests that width of palatal complex is influenced by location of tongue.[20,21] It is valuable to highlight that differences between genders are not always perceptible, since there are features that overlap both genders. Additionally, gender dimorphism does not express itself equally between individuals, it goes through morphological influences from the ethnic group, cultural habits, and age.[22]

The mean value of maxillary inter 1st premolar width, inter 2nd premolar width, inter 1st molar width and inter 2nd molar width were all higher in males than females and the difference were statistically significant.

This is ascribed to the fact that basal bones of the skull are larger in males than in females and the same might get echoed on the basal bone of the jaws and the dental arches that goes by the "Apical base theory" which states that dental arch form is initially shaped by the configuration of its supporting bone, which limits dental arch expansion.[23]

Relationship between arch size vary among gender indicating bigger sizes in males. Dentofacial relationship, the tissue that involves them, occlusion, dental arches variability and genetic component are related to the differences found in the maxilla and mandible, whereas coronal morphology and permanent teeth sizes are unchanged during growth and development process, except for nutritional abnormality or disorders inherited in other pathological conditions.[7]

The difference in mandibular intercanine width was found to be statistically insignificant (p - value 0.71 > 0.05). This finding is in conformity with studies conducted by Thumula Reshmi et al,[12] Rani S T et al,[10] Jonathan Daniel et al,[14] G Venkat Rao et al.[15] And in dissension with studies conducted by Santos et al,[11] Nadendla LK et al,[24] Gupta J et al.[25]

This finding could be due to significant changes that occur in the maxillary and mandibular dental arches and dentition in both males and females, including a clinically significant increase in tooth-size arch length (circumference) discrepancy.[26]

The difference in mandibular inter 1st premolar width was found to be statistically insignificant (p - value 0.78 > 0.05). This finding is in accordance with studies conducted by Thumula Reshmi et al,[12] Mohammad Khursheed Alam et al.[27] And in discordance with studies conducted by Forster M et al.[13] The difference in mean mandibular intercanine width and 1st inter premolar width was found to be statistically insignificant. This is attributed to the fact that the direction of mandibular growth is influenced by the tongue base position, as the anterior tongue pressure might influence on the rotation of mandibular corpus. Because of the lowered positioning of tongue, the balance between the tongue and buccinators muscle (buccinators mechanism) might be disturbed and this can be a reason for the arch constriction in maxilla. Mandible also constricts along with maxilla since maxillary and mandibular arches are mutual counterparts according to Enlow's counterpart principle.[20,21\]

The mean value of mandibular 2nd inter premolar width, 1st inter molar width and 2nd inter molar width were all higher in males than females and were statistically significant. This is attributable to the fact that musculature has been considered as the possible link for changes in the transverse dimension of mandibular dental arch. A number of studies have illustrated the influence of masticatory muscles on craniofacial growth. The general consensus is that individuals with strong or thick mandibular elevator muscles tend to exhibit wider transverse head dimensions. Muscular hyper-function causes an increased mechanical loading of the jaws. This in turn may cause an introduction of sutural growth and bone apposition which then results in increased transverse growth of the jaws and bone bases for the dental arches. It has been found that mean bite force values are higher in males than in females.[13] The increased bite force can be the reason for the increased arch width in males when compared to females.[28]

Limitations of conventional occlusal radiographs include distortion due to projection, processing errors and cannot be stored for a long term.

Establishing a computerized data bank of antemortem information on missing persons and post-mortem findings in disaster victims greatly facilitates and hastens the identification process. We propose that henceforth all dental hospitals acquire occlusal radiographs of all visiting patients to be archived digitally for the long term, so that they may be used as antemortem records for future for gender identification. We suggest that further studies with larger samples from multifarious ethnic groups be carried out using digital radiographs for gender determination in forensic science.

CONCLUSION:

In the present study we found that all linear measurements of maxillary and mandibular dental arches on occlusal radiographs were higher in males than females and most of them were statistically significant. The Inter 2nd molar width in both maxillary and mandibular dental arch was the best predictor for gender determination with an accuracy of 65%. The Predicted gender model showed a sensitivity of 60% and specificity of 70% in the Maxillary arch, whereas a sensitivity of 70% and specificity of 60% in the Mandibular arch and the overall accuracy of 65% of grouping correctly the originally grouped cases in both the arches.

We found significant sexual dimorphism in linear measurements of maxillary and mandibular dental arches. Therefore, we advocate that linear measurements of maxillary and mandibular dental arches on occlusal radiographs can be very useful for gender determination. We propose that henceforth all dental hospitals acquire occlusal radiographs of all visiting patients to be archived digitally for the long term, so that they may be used as antemortem records for future for gender identification in forensic science.

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